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MONITORING AND CONTROL REQUIREMENT DEFINITION STUDY FOR DISPERSED STORAGE AND GENERATION (DSG)

FINAL REPORT

Volume III

October 1980

Prepared for

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY

and

NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

Submitted by

GENERAL ELECTRIC COMPANY
CORPORATE RESEARCH AND DEVELOPMENT

GENERAL ELECTRIC

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MONITORING AND CONTROL REQUIREMENT DEFINITION STUDY FOR DISPERSED STORAGE AND GENERATION (DSG)

SRD-80-042-III

FINAL REPORT

Volume III

October 1980

Appendix B

STATE OF THE ART, TRENDS, AND POTENTIAL GROWTH OF SELECTED DSG TECHNOLOGIES

Prepared for

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY

(Contract No. 955456)

and

NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

(Agreement No. ER 320-78/79 EUET)

Submitted by

GENERAL ELECTRIC COMPANY
CORPORATE RESEARCH AND DEVELOPMENT
Schenectady, New York 12301

GENERAL ELECTRIC

FOREWORD

This Final Report is the result of a year-long effort on Monitoring and Control Requirement Definition Study for Dispersed Storage and Generation (DSG) conducted by the General Electric Company, Corporate Research and Development, for the Jet Propulsion Laboratory, California Institute of Technology, and the New York State Energy Research and Development Authority.

Dispersed storage and generation (DSG) is the term that characterizes the present and future dispersed, relatively small (<30 MW) energy systems such as those represented by solar thermal electric, photovoltaic, wind, fuel cell, battery, hydro, and cogeneration. To maximize the effectiveness of alternative energy sources such as these in replacing petroleum fuels for generating electricity and to maintain continuous reliable electrical service to consumers, DSGs must be integrated and cooperatively operated within the existing utility systems. To effect this integration may require the installation of extensive new communications and control capabilities by the utilities. This study's objective is to define the monitoring and control requirements for the integration of DSGs into the utility systems.

This final report has been prepared as five separate volumes which cover the following topics:

VOLUME I - FINAL REPORT

Monitoring and Control Requirement

Definition Study for Dispersed Storage and Generation

VOLUME II - FINAL REPORT - Appendix A

Selected DSG Technologies and Their General Control Requirements

VOLUME III - FINAL REPORT - Appendix B

State of the Art, Trends, and Potential Growth of Selected DSG Technologies

VOLUME IV - FINAL REPORT - Appendix C

Identification from Utility Visits of Present and Future Approaches to Integration of DSG into Distribution Networks

VOLUME V - FINAL REPORT - Appendix D

Cost-Benefit Considerations for Providing Dispersed Storage and Generation of Electric Utilities

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ACKNOWLEDGMENTS

Throughout this study we have benefited greatly from the help offered by many people who are knowledgeable in specific areas of the dispersed storage and generation technologies studied and in the fields of communications, control, and monitoring. We particularly wish to acknowledge the efforts of and discussions with Dr. Khosrow Bahrami and Dr. Harold Kirkham, each of whom have served as technical manager in the Jet Propulsion Laboratory, and Dr. Fred Strnisa, project manager, New York State Energy Research and Development Authority.

We also wish to thank the various people with whom we met during our utility visits. The following utilities have provided useful information regarding DSG activities at their organizations:

Niagara Mohawk Power Corporation, Syracuse, New York

San Diego Gas and Electric Company, San Diego, California

Blue Ridge Electric Membership Corporation, Lenoir, North Carolina

Public Service Electric and Gas Company, Newark, New Jersey

In addition, we thank our many associates in General Electric Company who have helped so much in our understanding of the selected DSG technologies and in the integration of DSGs into the existing electric utility system. In particular, we thank J.B. Bunch, A.C.M. Chen, M.H. Dunlap, R. Dunki-Jacobs, W.R. Nial, R.D. Rustay, and D.J. Ward.

The help of Dr. Roosevelt A. Fernandes of Niagara Mohawk Power Corporation in several phases of the work covered in this report is acknowledged with thanks. Also, Dr. Fred C. Schweppe, consultant, has been of considerable benefit in the conduct of this project and his efforts have been appreciated.

Harold Chestnut

Robert L. Linden

ABSTRACT

A major aim of the U.S. National Energy Policy, as well as that of the New York State Energy Research and Development Authority, is to conserve energy and to shift from oil to more abundant domestic fuels and renewable energy sources. Dispersed Storage and Generation (DSG) is the term that characterizes the present and future dispersed, relatively small (<30 MW) energy systems, such as solar thermal electric, photovoltaic, wind, fuel cell, storage battery, hydro, and cogeneration, which can help achieve these national energy goals and can be dispersed throughout the distribution portion of an electric utility system.

The purpose of this document is to identify the present status, trends, potential growth for selected DSGs, and implications on DSG monitoring and control. Based on current projections, it appears that DSG electrical energy will comprise only a small portion, from 4 to 10%, of the national total by the end of this century.

In general, the growth potential for DSG seems favorable in the long term because of finite fossil energy resources and increasing fuel prices. Recent trends, especially in the institutional and regulatory fields, have favored greater use of DSGs for the future. This study has assimilated the considered estimates and opinions of others, for the DSG markets and the DSG's ability to serve them. So far as possible a cross section of various sources has been included in composite projections.

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Section B1

INTRODUCTION

B1.1 BACKGROUND

A major aim of the United States national energy policy is to conserve energy and to shift from oil to more abundant domestic fuels and renewable energy sources. Dispersed storage and generation (DSG) is the term that characterizes the present and future dispersed, relatively small (<30 MW) energy systems, such as solar thermal electric, photovoltaic, wind, fuel cell, storage battery, small hydro, and cogeneration -- all systems that can help to achieve these national energy goals. A great deal of the national energy research and development effort is being devoted to energy systems of these kinds which, because of their size, siting, and input energy considerations may be dispersed throughout the distribution portion of an electric utility system.

The use of dispersed storage and generation (DSG) in electric utility distribution systems, while not new,* seems destined to increase in quantity and variety. It is important to note that three basic characteristics are represented by the seven DSG technologies selected for examination in this study. The characteristics establish the usefulness and value of these DSGs and their application within the electric utility power supply framework.

Essentially the basic characteristics and the associated DSG types are as follows:

Characteristics	DSG Type
A. Dispersed Storage	Battery Storage
B. Dispersed Generation, on demand	Fuel Cell Cogeneration (with constraints) Hydro (with storage)
C. Dispersed Renewable Generation, intermittent/random	Solar Thermal Electric Photovoltaic Wind Hydro (run of river)

*Small hydroelectric generation has existed since the beginning of the electrical industry in the 1880's. Cogeneration has been employed since the early 1900's in the United States.

B1.2 PURPOSE

The purpose of this document is to identify present status, trends, potential growth for selected DSGs,* and implications on DSG monitoring and control. Based on current projections, it appears that DSG electrical energy production will comprise only a small portion of the national total for the remainder of this century. The established DSG technologies of hydroelectric generation and cogeneration appear to have resource or potential application constraints, and the new DSG technologies face the traditional evolutionary process from conception to maturity. Attendant with the development of new DSG technologies is the need to develop the supporting manufacturing base and industry infrastructure. Historically, a successful new technology growth follows an "S" curve taking 10, 15, or 20 years to reach wide-scale commercial application.

In general, the growth potential for DSG appears favorable in the long term because of finite fossil energy resources, long development and implementation time requirements for nuclear breeder technology, and even longer time requirements for fusion energy. During the next 20 years, DSG will probably be encouraged by energy demand growth, energy cost increases, petroleum supply limitations, decreasing natural gas supply, and the major task of accelerating coal and nuclear electric power capacity. Governmental policy and regulatory requirements may also have a significant effect on DSG implementation, as will continued pressures and funding for DSG development and cost reductions.

Within the selected group of seven different DSG technologies, there is a wide range of state of the art, trends, and potential growth. As used, "state of the art" will refer to the present status of a technology and will emphasize present methods for achieving successful application. Appendix A of this report, "Selected DSG Technologies and Their General Control Requirements," has identified the present state of the art in the near-term, as well as longer term trends.

The word "trend" has been broadened to refer not only t technical advances which may take place but also includes institutional, regulatory, social, and economic factors which can have pronounced effect on DSG utilization and growth.

"Potential growth" is used to indicate the possibility for growth of the specific DSG market, rather than a forecast of a

*Selected DSGs for purpose of this study include the following seven technologies:

1. Solar-Thermal Electric Energy Conversion
2. Photovoltaic Energy Conversion
3. Wind-Electric Energy Conversion
4. Fuel Cell Energy Conversion
5. Storage Battery, Energy Storage
6. Hydroelectric Energy Conversion
7. Cogeneration, Combined Heat and Electricity Production

most likely growth for each technology. For the newer DSG technologies, cost predictions are difficult while the DSG is still in the developmental or experimental stages. Furthermore, relative success of competing DSG technologies 10, 15, or 20 years hence is also difficult to predict. This study has assimilated the considered estimates and opinions of others, for the DSG markets and the DSG's ability to serve them. So far as possible a cross section of various sources has been included in composite projections.

Section B2

INFLUENCE FACTORS AND TRENDS

B2.1 INTRODUCTION

Our whole dynamic economic-social-political structure affect: the conduct and determination of commerce and industry in the Uni States, including new technological activities such as DSG. In a dition, foreign policies, especially those which affect energy su ply, influence new technologies such as DSGs. Energy resources, supply, demand, and prices have become a major influence in domes and world economy. The interrelationships among economic, social and political factors are infinitely complex and beyond the scope of this study. Observations on these factors and their trends ha been assimilated and noted since they directly or indirectly affe the DSG technologies. Because of the recent instability and unce tainty in economic, and particularly, energy resources, and in su ply, demand, and price areas, recent forecasts of trends have sho increasingly wider bands of low-to-high range (greater uncertaint Consequently in preparing this document, the reports of energy su ply companies, electrical industry, governmental agencies, and in dependent research o: ,anizations have been sampled in order to ob tain a cross sectio. of opinions regarding trends in economic, so and political factors. Tables in this document reference these sources.

B2.2 ECONOMIC FACTORS AND TRENDS

Historically, there has been a close correlation between the long-term level and growth rates of the United States economy and energy consumption. Electrical energy consumption has increased at a faster rate than total energy consumption, as its industrial commercial, and residential use expanded. From 1920 to 1977, the average annual growth rates for the gross national product (GNP), total energy, and electrical energy consumption were approximatel 3.7, 3.3, and 6.6%, respectively. During this period, the popula tion's average annual growth rate was 1.26%. The sustained growt in the GNP, total energy consumption, and electrical energy con- sumption were achieved during a period of relatively low price energy. This era has apparently ended and major adjustments are in progress. A sampling of projections regarding population, eco omy, total energy consumption, and electrical energy consumption reveals that the United States growth rates are expected to decre from historical values.(1) On this expectation there appears to consensus.

Regarding the degree and timing of the slowing down of these major factors, there are diverse opinions. The diversity can be accounted for in the differences in assumptions and to some exten the intentional or unintentional bias of the organization or indi viduals conducting the studies. It is not the intent of this st

to compare or comment on specific studies, but rather to try to derive an overall picture, and a sense of how DSG technologies and their implementation may be affected. Table B2.2-1 shows the range of values for basic economic-energy factors growth rates, both historical and projected. These factors have implications for potential DSG technology growth. "Energy for Electricity" listed in Table B2.2-1 has particular significance since its figures predict an increasing proportion of the energy consumed nationally will be used for electricity production.

Table B2.2-1

AVERAGE ANNUAL GROWTH RATES, IN PERCENT, FOR MAJOR ECONOMIC FACTORS *

Major Economic Factors	Historical Average Annual Growth Rate 1920-1977, %	Projected Average Annual Growth Rate, % 1977-2000 (Values Listed Indicate Ranges)		
	Actual	Low End	Median	High End
United States Population	1.26		0.8	
Economic (GNP)	3.7	1.5-2.95	2.4-3.3	3-3.75
Total Energy Consumption	3.3	1.0	1.9-3.5	2-4.0
Electrical Energy Consumption	6.6	2.0-4.0	3.0-5.3	4-6.6

* Reports of organizations from which figures were obtained represent a cross section. Organizations included are: U.S. Department of Energy/Energy Information Administration, U.S. Department of Commerce, U.S. Department of Interior, EEI, EPRI, EBASCO, Bankers Trust, and others. Figures were those publicly presented during the general time period of 1977-1978.

	1977	Projected for Year 2000		
Energy for Producing Electricity as Percentage of Total Energy Consumed	29	20	35	50

Concerning the overall potential for DSGs, the price of various fuels and the proportion of their mix used to generate electricity will be of equal or greater effect than the major economic-energy factors in Table B2.2-1. In particular, the price of the fuel which could be displaced by DSGs using solar, wind, or hydro energy will have a direct effect on their economic viability. At this time, fuel price projections are very difficult to make with confidence.

Recent studies that have been made include a range of values for future fuel prices that reflect uncertainty in the ability to predict future fuel prices. Also, new studies include high, middle, and low values and these bands can be relatively wide. To illustrate fuel price trends, Figure B2.2-1 shows the mid-range values of DOE/EIA(1) and of EPRI(2) studies made in the 1978-1979 time period. Sample values for November 1979 are shown for comparison. It should be emphasized that the source documents contained a band of values and recent price increases appear to be moving petroleum prices above the mid-range values. The main point of Figure B2.2-1 is to indicate that fuel prices are expected to increase and also to indicate that the relative differences among petroleum, coal, and nuclear prices are to be expected. Since the U.S. energy supply structure will include major imports of petroleum for the remainder of this century, the rapidly increasing price of petroleum indicates increasing possibilities of DSG economic viability in this time period.

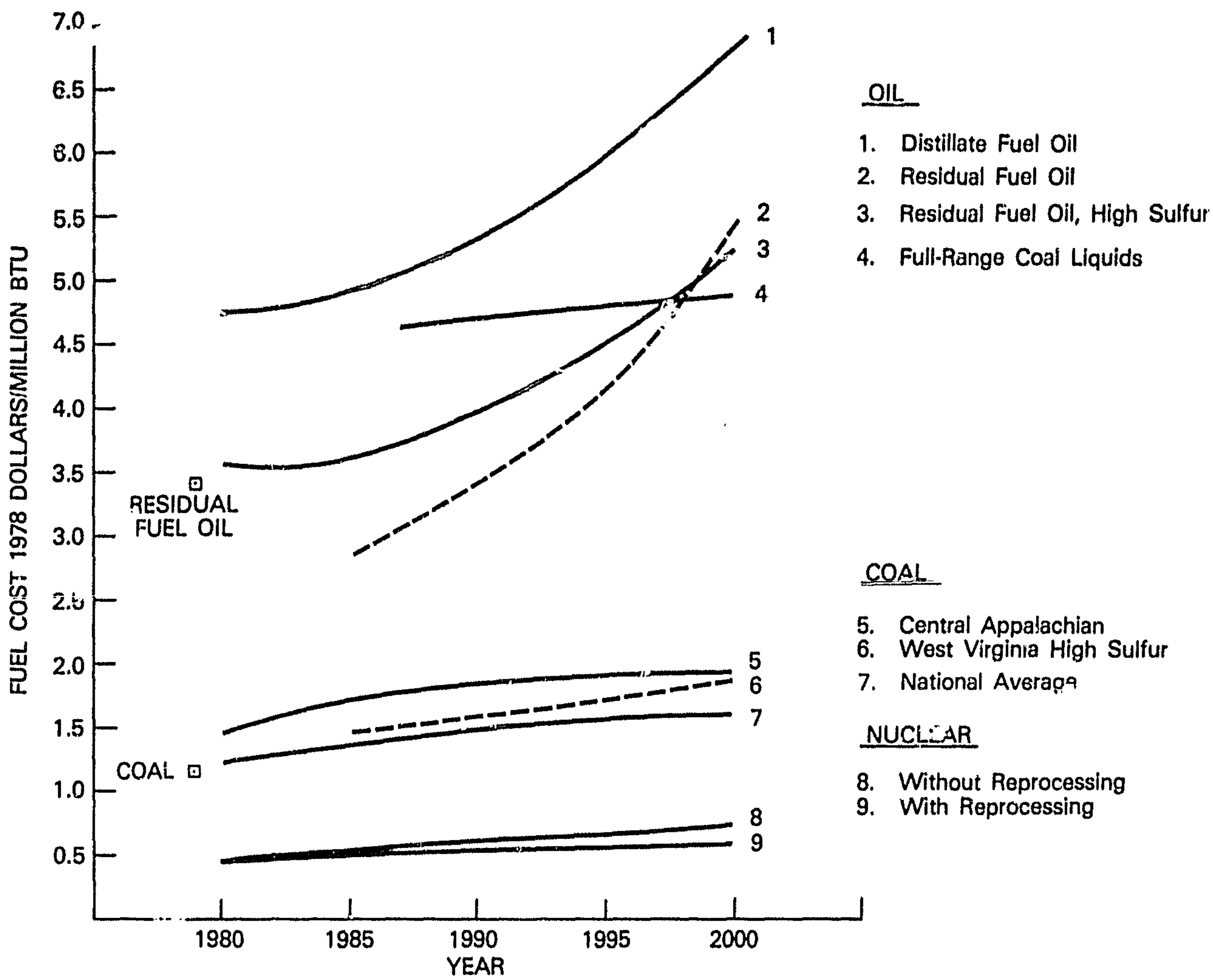
The magnitude of total electrical energy production and generating capacity between 1977 and 2000 is shown in Table B2.2-2. These values predicted for year 2000 are median values. There appears to be a consensus that the proportion of energy consumed in the form of electrical energy is going to increase.

Considering the economic, energy, and electrical industry statistics in Tables B2.2-1, B2.2-2 and Figure B2.2-1, it is important to note that even a small percentage of the total generating capacity required by year 2000 if supplied by DSG's units could amount to a large number of DSGs. If economic viability is achieved by DSGs, their potential is considerable. With a manufacturing base to support DSGs, the remainder of the 20th and the beginning of the 21st century could see increasing rates of DSG expansion. The subject, "DSG Technologies - Potential Growth" is treated by individual DSG types in Section B4.

B2.3 SOCIAL FACTORS AND TRENDS

The major social factors that influence the electrical utility industry are demographic, living patterns, and attitudes. Demographic factors (population, distribution, births, marriages, mortality, health, age patterns, and so forth) have a direct effect on economic factors and these are included in the economic and energy projections discussed previously. As a "developed" nation, United States living patterns, barring serious disruptions, are likely to change gradually. This fact is in contrast to that of the developing nations whose living patterns are evolving and changing more rapidly and thus leave the area of attitudes regarding energy use, production, and consumption as factors to consider.

The social attitudes that are most likely to directly affect electrical energy conversion/production are those relating to types of fuel, siting of plants, environmental protection, and regulation. These positions all relate to political and policy factors wherein



SOURCES

1, 3, 4, 5, 7, 8, 9 EPRI Technical Assessment Guide, EPRI PS-1201-SR, July 1979.

2, 6 DOE/EIA Annual Report to Congress 1978, DOE/EIA-0173/3.

□ - DOE/EIA Monthly Energy Review, March 1980, DOE/EIA-0035/03(08), P. 89 (November 79 Data).

Figure B2.2-1. Cost of Fuel Delivered to Electric Utilities

Table B2.2-2

TOTAL ELECTRICAL ENERGY PRODUCTION AND GENERATING CAPACITY

	Year		
	1977(*)	2000	
		DOE/EIA(†)	EPRI(††)
Total U.S. electric utility electrical energy production in billions of kWh (electric utility plus industrial)	2124 (2212)	5555(§)	6100
Peak load (GW)	396.35		1080
Total generating capacity (GW)	550.0		1300
Load factor, percent	61.4	67	63
Reserve margin, percent	30.2(||)	20	20
New generating capacity (GW), required to supply increasing demand and replace retired capacity (by year 2000)			925
Average U.S. electrical energy annual growth rate, percent(#)			
1920-1977	6.6		
1977-2000		4.7	4.6

(*) Statistical History of U.S., Energy Information Administration.

(†) Annual Report to Congress 1978, U.S. Department of Energy, Energy Information Administration, DOE/EIA-0173/3.

(††) EPRI - Technical Assessment Guide, EPRI PS-1201-SR, Special Report, July 1979.

(§) Year 2000 values extrapolated from 1995 mid-range energy sales projection adjusted by 10% transmission distribution loss.

(||) EEI Statistical Yearbook for 1977, 18 Year Average = 25%.

(#) Growth rate is expected to vary by region with relatively large variations. For example, for New York State, a 2.1 % growth rate is forecast through 1994 by the "New York State Energy Master Plan and Long-Range Electric and Gas Report," draft report, August 1979.

the attitudes of the public eventually are incorporated. In terms of the types of fuel and public attitudes to various types of fuel, the perceived actual and potential impact on the environment seems to currently be the predominant influence. The full realization of the finite nature of the energy resources available and their relative quantities are only beginning to be understood by the general public. Thus, the need to seriously begin transfer from a petroleum-oriented energy structure to a coal-and-nuclear structure has yet to be recognized. In view of this, the environmental concerns predominate, impeding progress toward constructive solution of the overall problems. Thus, the major near-term effect of social attitudes will be the influence that they have on environmental protection matters including pollution, natural resource conservation, and siting of facilities. These concerns will be reflected in ensuing policies, legislation, and regulation with the apparent near-term trend of continued stringent requirements.

B2.4 POLITICAL FACTORS AND TRENDS

The most nebulous concern, yet probably the most critical factor to the orderly solution of the economic-energy related problems, is in the major area of policy development by our government at all levels. There is an urgent need for a coherent policy and its translation into consistent legislation, regulations, taxation, and business incentives. In addition, direction and emphasis on realistic proportionment of research and development efforts, magnitude, and timing are required to support policy. This is not the document in which to elaborate or critique these matters. Rather, some observations regarding influencing factors and their trends, as regard DSG potential, are the immediate matter for discussion.

Various regulatory, licensing, taxation, and incentive policies are evolving which are being translated into working documents. A major incentive for encouraging DSGs could result from recent rules adopted by the Federal Energy Regulatory Commission (FERC), the commision that implements regulations pertaining to Section 210 of the Public Utility Regulatory Policies Act of 1978 (PURPA - Section 210). For DSGs, which utilize renewable or "inexhaustible" energy sources, the major influence factors will be those associated with regulatory and environmental concerns. Solar thermal electric, photovoltaic, wind, and hydro are involved in land, water, space, sunlight, and aesthetic aspects of environmental regulation. The specifics for each DSG technology as they affect potential growth are treated in Section B4. Federal regulation and allocation of petroleum and natural gas for electric power generation and major fuel burning installations could have an impact on DSG plants. The Powerplant and Industrial Fuel Use Act (PIFUA) prohibits or restricts the use of petroleum and natural gas fuels for generation and boilers. At this time the PIFUA has not been clarified by specific FERC rules. It is noted however that certain types of DSGs which use petroleum fuels could be adversely affected. The same is true of conventional central station power plants using petroleum and natural gas fuels. Second-generation fuel cell technology (specifically molten carbonate fuel cells) is aimed at utilizing coal-derived liquids and gases.

These low- and high-temperature fuel cells would not be adversely affected by PIFUA regulations, and as these fuels become available, widespread application could result.

Storage battery technology appears to be the least directly affected by policy matters. However, in order to charge storage batteries, there must be sufficient system generating capacity installed for recharging plus normal off-peak load. To provide this base load generating capacity will require the construction of efficient coal and nuclear plants. From an environmental impact standpoint, storage batteries require solutions to safety, such as fire prevention, and environmentally acceptable disposal methods for retired battery materials.

Cogeneration is the most complex DSG from the standpoint of regulatory, taxation, and incentive policies. Potential cogeneration applications are confronted by permissible fuel types and allocation, governmental regulation of electrical energy sale, taxation rules and incentives, governmental reporting, environmental concerns of air and water quality, and siting constraints.

At present, there is a general attitude favoring the DSG technologies and some action has started to make regulations more favorable,* licensing easier and faster, and taxation policy more favorable. The timing and degree to which these actions are accomplished will influence DSG technologies. If action and resolution takes too long or is insufficient, it may have a retarding or discouraging effect on DSGs.

*In recent action (Federal Register Vol. 45, No. 38, Feb. 25, 1980, page 12214-12237) the Federal Energy Regulatory Commission adopted regulations that implement Section 210 of the Public Utility Regulatory Policies Act of 1978 (PURPA). The rules require electric utilities to purchase electric power from qualifying cogeneration and small power production facilities (at rates that are "just and reasonable and in the public interest") and provide for the exemption of qualifying facilities from certain federal and state regulation.

Section B3

MATURITY OF SELECTED DSG TECHNOLOGIES

B3.1 DSG CATEGORIES OF DEVELOPMENTAL STATUS

In order to identify the state of the art and trends of the DSG technologies, it is important to realize that the seven selected technologies fall into different categories of development status. For example, small hydroelectric power plants have been used for many years and hydropower is relatively mature in its basic "development-to-use" cycle. However, features such as remote and automatic control may not have been used in older hydro installations so that new control/communication designs and procedures may be required.

Likewise, cogeneration has been used by some companies for many years, principally to generate process steam and electric power for local consumption. Changes introduced here might not be so much of a technical nature as would be the case in regulatory or institutional arrangements that would enable private industry to work more closely with public or private utilities to expand cogeneration.

Wind generation is in an intermediate stage of technical development. Previously, small wind generators have operated independently of the electrical distribution grid. Experimental and prototype units are under construction and test and are beginning to be connected to utility distribution systems. In the past, hydroelectric, internal combustion engine, and combustion turbine prime mover generators of 0.2 to 3.0 MW have been connected and operated on utility distribution systems. Therefore, there is little speculation about whether wind technology will operate. The concern is whether it can perform economically and reliably, and how to coordinate wind generators with the rest of the grid.

Other DSG technologies such as solar thermal electric, photovoltaic, and fuel cells are in an experimental development stage. Therefore, the electric utility industry has not yet used them. Photovoltaic and fuel cell technology has been used in the United States space program and in a few, small isolated applications. Photovoltaic systems of several hundred kilowatt size are just beginning to be designed and built to operate in conjunction with electric utility systems. Photovoltaics also need significant cost reduction to be economically viable. Furthermore, since these technologies involve the fabrication and construction of equipment that has not been built in large quantity, several years will be required to put the necessary manufacturing plant, organizations, and people into place to produce a significant quantity of electrical energy.

B3.2 DSG LIFE CYCLE DEVELOPMENT

In discussing the state of the art of each of the DSG technologies it is useful to consider the life cycle of a product or system from initial concept and experimentation, through its useful commercial period, continuing its product maturity, and finally to its phaseout to make way for an improved design or a new technology. Such a life cycle consideration is important because it serves to indicate what matters are or should be receiving the major attention. During the initial concept and development, or experimental stage of the life cycle, emphasis is placed on the feasibility and physical principles involved. Concern with application aspects such as remote monitoring and control tends to receive less attention. During final design and preproduction (prototype) testing, attention should be devoted to remote monitoring and control, especially for unattended DSGs to optimize their usefulness when they reach commercial operation.

B3.3 PRODUCT DEVELOPMENT

For purposes of categorizing the state of the art of the seven selected DSGs, four states of product development may be defined as follows:

State of Development	Status of Technology
1. Experimental	The condition is that of a preliminary design to prove feasibility. Some key experiments have been run, but prototype manufacture has not yet been started for major portions of the technology or the system. There is little or no use of the technology by utilities.
2. Preproduction	One or more working systems have been built and are preforming in a utility environment. Although the equipment may be similar to production models, it has not been fabricated using production methods. Therefore, costs tend to be greater than production cost estimates.
3. Commercial	Systems using production equipment are operating in utility systems. Greater reliability, easier maintainability, and lower costs are better realized in this stage than during preproduction.

4. Mature — The system is in widespread use by utilities and the advantages of large-scale production, installation, and operational experience are being realized. New applications of established designs are being sought to broaden the production base.

B3.4 COSTS

To illustrate the effect of decreasing costs with a degree of maturity, refer to Figure B3.4-1 which shows projected solar thermal electric costs, as estimated by the Aerospace Corporation.(3) Figure B3-1, indicates that a 1 MW solar thermal electric system would cost about $5000/kW in 1985, $3000/kW in 1990, and $1800/kW in 1995 - all of these estimates being expressed in 1977 dollars.

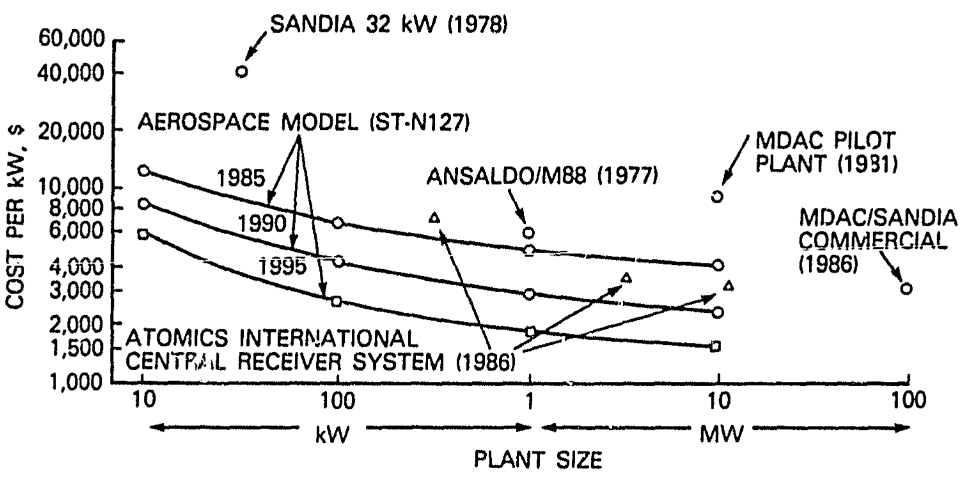


Figure 3.4-1. Comparison of Aerospace Model of Solar Thermal Electric System Total Costs ($/$KW_e$) with Contractor Data, 1977 Cost Base, Report ATR-78(7692-01)-1

B3.5 PERCEIVED STAGES OF DEVELOPMENT

To obtain an indication of the perceived stages of development of the seven selected DSG technologies, refer to Table B3.5-1. These designations of the degree of maturity are the contractor's judgment. For some technologies, more than one development stage is shown with the stage with parentheses representing the secondary condition.

Because of the differences in the various DSG technology stages of development, and various timing of their changing from one stage to the next, each of them will be described separately in Section B4.

Table B3.5-1

PERCEIVED STAGE OF DEVELOPMENT
OF
SELECTED DSG TECHNOLOGIES

DSG Technology	Stage of Development			
	Experi-mental	Prepro-duction	Commercial	Mature
Solar Thermal Electric	X			
Photovoltaic	X	(X)		
Wind	(X)	X		
Fuel Cell				
Low temperature		X		
High temperature	X			
Storage Battery				
Low temperature	X	(X)		
High temperature	X			
Hydro			(X)	X
Cogeneration			X	(X)

NOTE: Stages indicated by (X) represent a secondary position.

Section B4

POTENTIAL GROWTH OF DSG TECHNOLOGIES

The potential growth of DSG technologies in electric utility distribution systems depends on the following factors:

- Economic viability
- Technical viability
- Societal acceptance
- Political and regulatory requirements
- Environmental factors

The projected need for electrical generation is rising, as discussed in Section B2, and there is room for DSG technologies if they qualify. This section describes potential growth possibilities for DSG technologies, their stage of technical development, potential costs, and their availability to meet the electric utilities' needs for power at the distribution level.

B4.1 SOLAR THERMAL ELECTRIC

Small solar thermal electric (STE) power plants in the 1 to 10 MW electrical output range are in the experimental stage. The Jet Propulsion Laboratory Engineering Experiment Number 1 of the Small Power Systems Application Project[4] represents a current undertaking to develop, implement, and test the conceptual designs which presently exist.

During the course of design studies such as these, a number of technical problems have been analyzed but solutions have not been reduced to practice. Representative of such problems might be the solar collector and its associated solar tracking means, the maintenance and life characteristics for the overall equipment, and the steam loop control. These design items are cited as being elements where continued efforts may be required. Mention of these items is not intended to indicate specific areas of design limitations. However, such items do suggest the possibility of changes in cost and in time schedules that might influence the potential growth in use of solar thermal electric technology.

For an arbitrary plant size of 1 MW, a hypothetical timetable from experimental through preproduction, to commercial production might represent a cumulative buildup of plants installed as illustrated on Figure B4.1-1.

Figure B4.1-1 estimates that 50 units of 1 MW each might be operating by 1990, 500 units of 1 MW by 1995, and 2000 units of 1 MW each by the year 2000. The estimated unit price (in 1978 dollars) for a 1 MW plant fully equipped is \$3500/kW in 1990, \$1800/kW in 1995, and \$1300/kW in 2000.[5] These cost numbers

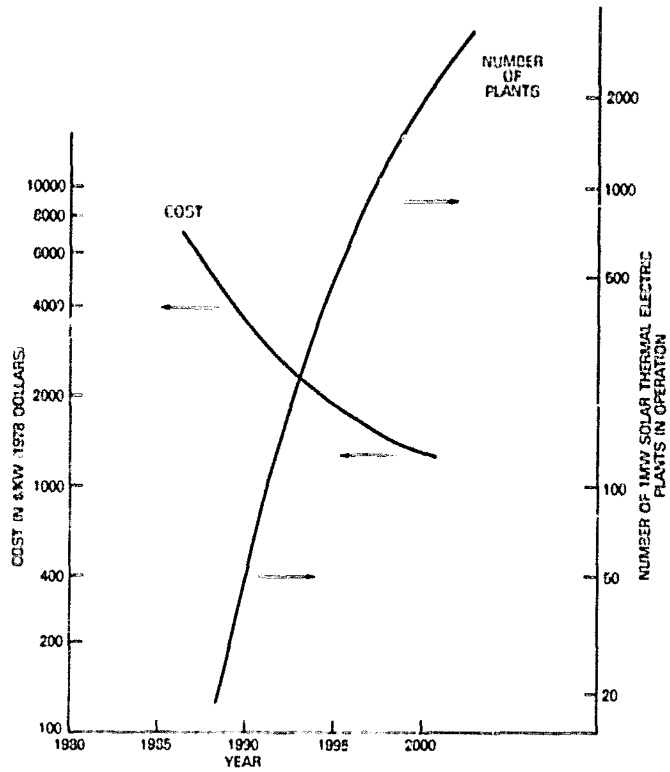


Figure B4.1-1. Estimate of Number and Cost of 1 MW Solar Thermal Electric Plants Versus Year

should be considered as management objectives for solar thermal electric equipment (1 to 10 MW), rather than verified design estimates.

While design and experimental activity is progressing on small solar thermal electric plants which use multiple collectors, there is also activity directed to large central tower/heliostat designs and central tower hybrid solar thermal power plants. There are advocates for each of the system types. Since the central receiver (solar only) and hybrid solar thermal plants probably will be larger than DSG size (30 MW), they have not been included in DSG considerations. However, a comment by EPRI is of interest regarding the hybrid solar thermal type plant. In the EPRI Research and Development Program Plan for 1979-1983, PS-830-SR July 1, 1978, Page 1I-54, the following statement is made. "Hybrid solar thermal plants (gas turbine with Brayton cycle solar operation and oil-fired backup) will be most competitive when used only to meet peaking and intermediate load requirements and will be logistically viable only in the Southwest. For these reasons, the amount of capacity and generation in the year 2000 will be constrained."

Although these statements by EPRI apply most specifically to larger, central tower hybrid solar thermal electric plants, they also have some relevance to small solar thermal electric plants. The insolation level is highest in the Southwest, and therefore the

amount of energy potentially available is greatest there. Also, in the Southwest, the competitive position of coal-fired plants versus hybrid solar thermal plants would be the same as for the smaller plants.

However, if energy prices continue to rise to higher levels as they have over the past few years, small solar thermal electric generation may become cost competitive. In this situation, there may be other parts of the United States where sufficient solar radiation is available to justify solar thermal electric generation.

In summary, the solar thermal electric technology is in the experimental stage and may not reach commercial availability until 1990. However, the potential for growth in the time period from 1990 to 2000 appears to be of the order of 200 to 1000 MW per year. As a result of surveying STE technology in this DSG study effort, a conservative estimate of the number of monitoring and control installations which may be required for DSG-size solar thermal electric plants appears to be 10 to 20 per year beginning in 1990 and increasing to 100 to 200 per year by 2000.

B4.2 PHOTOVOLTAIC

Photovoltaic energy conversion for electric utility DSG application is in the experimental stage of development. Considerable funds are being expended in research, development and demonstration by the government, by utilities, and by private industry. The DOE budget for the photovoltaic program in fiscal year 1979 was 118.5 million dollars and 130 million dollars for 1980.[6] Since the primary impediment to large-scale application of photovoltaics is high cost, major efforts are concentrated on reducing the cost of photovoltaic cells, collectors, arrays, and the balance of the system. Major reductions in cell costs are required for large-scale economic viability. Concurrent with reducing cell costs, efficiency improvements are also required. While the major problem is the development of low-cost, acceptable efficiency cells and collectors, there are other technical problems to be solved consistent with the cost and efficiency requirements. Some examples of these other technical problems are:

- Acceptable cell life
- Cell encapsulation integrity
- Voltage surge protection (particularly from lightning)

Technical progress is being made through research and development and demonstration systems are being built. The demonstration systems bring all aspects of system design together and prove them in actual operation and testing. Experiments have been made with photovoltaic flat plate systems of 20 to 500 watts. These small PV systems have been for isolated sites such as remote TV receiver stations, weather stations, forest lookout towers, traffic signs, ocean buoys, food refrigeration at an isolated village, construction camp power, and so forth. More recent installations

of larger photovoltaic systems have been made, such as a 50 kW irrigation project in Mead, Nebraska. Furthermore, size increases are planned for use at remote villages such as the joint United States/Saudi Arabia project for a 350 kW installation in 1981. As a step in extending application experience to systems which will be interconnected to electric utility distribution systems while supplying local loads, DOE is finalizing the award of nine contracts using flat plate and concentrator technology.[7] The preliminary designs (29 Phase I system designs, 20 to 500 kW) have been completed, and for the nine selected designs, contracts for Phase II and Phase III Purchase and Construct are scheduled for 1981 completion. Thus design, construction, operation, and testing of intermediate size photovoltaic systems for connection to electric utility systems are in progress and scheduled for completion in the early 1980's. (Note that power ratings in kilowatts or megawatts are peak power output ratings at maximum solar insolation conditions.)

DOE market analysis[6] indicates a potential for major markets at installed system costs (1980 dollars) of 850 to 1,800 $/kW for residential applications, 1000 to 1900 $/kW for intermediate load centers, and 650 to 1350 $/kW for utility (central power) applications. DOE cost goals for grid-connected photovoltaic systems are 1600 $/kW for 1986 residential and intermediate load center systems, and 1100 to 1300 $/kW for 1990 electric utility central station type systems. As an indication of the cost breakthroughs that are required, DOE contract award announcements for the nine systems recently awarded for various concentrator and flat plate systems range from $16,700/kW to $30,900/kW[7] (includes final design costs). Thus major reductions in cost are required for economic viability. Other studies, and particularly a recent EPRI study,[8] indicate that the need for cost reductions in the same range as indicated by DOE must be realized to permit significant potential electric utility market penetration.

Regarding the amount of photovoltaic generating capacity which might be anticipated for the purposes of DSG control and monitoring planning, recent documents provide a basis for estimates. President Carter's "Domestic Policy Review of Solar Energy,"[9] shows a range of 0.1 to 1.0 quad of primary energy displacement in the year 2000 (1 quad = 10^{15} Btu). This range derives from varying assumed conditions, with 1.0 quad representing the maximum practical value. The DOE National Photovoltaic Program,[6] equates 0.1 quad of primary energy displacement to 4300 MW of (peak) photovoltaic generating capacity. One quad would represent 43,000 MW or approximately 3-1/2% of total installed capacity anticipated in year 2000. An EPRI study of photovoltaic power plants,[8] in examining penetration "impacts," projects that in the year 2000 approximately 0.4% of the nation's electric utility generating capacity might possibly be photovoltaic. The study notes that "the ultimate penetration of PV plants depends upon the advancement of the state of technology from present levels which are not economically viable. Estimates of the rate of advancement of PV technology are essential, but considerably uncertain." Regarding economic viability the report states, "even with the most optimistic value of PV plant cost, economic

viability is highly dependent upon the characteristics of individual utilities, the assumptions regarding future economic conditions and generation mix, and the feasibility of assigning capacity displacement value to PV plants."

With the foregoing projections and the major breakthroughs required, an installed peak capacity of 5000 MW might be assumed as a value for planning DSG monitoring and control requirements. The number of installations of residential, individual load center, and central station plants is not clear at this time. However, the National Photovoltaics Program[6] plan forsees commercial readiness for residential (10 kW) and intermediate (100 kW to 5 MW) PV systems in 1986, and commercial readiness for central station (200 MW) PV systems in 1990. Thus residential and intermediate-sized systems, analogous to DSG sizes are anticipated first. The number and sizes of PV systems by year 2000 are given in Table B4.2-1

Table B4.2-1

ESTIMATED PHOTOVOLTAIC UNITS BY YEAR 2000

Type	Rating (kW)	Number of Units	Installed Capacity (MW)
Residential	10	125,000	1250
Intermediate	1,000	3,750	3750
Central Station	200,000	5	1000

There will be a range of PV system sizes within each category and for the intermediate size the lower end of the range, i.e., 500 kW, will probably be private commercial ownership and the upper end, i.e., 5 MW or larger, will tend to be utility applications. The number of installations is highly speculative at this time. It is expected that the early commercial stages of PV system growth will follow an exponential curve. An estimated growth curve for intermediate size (1 MW) photovoltaic installations is shown on Figure B4.2-1.

B4.3 WIND GENERATION

In terms of the previously defined four development stages, wind generation is in the "preproduction" stage. The physical principles involved in wind generation are relatively well-established. Improvements in propeller blade design for strength, life, and cost, and improvements in generator speed control are in progress. Other improvements and cost reductions are also underway.

A number of wind generators of small, medium, and large size are operating and experience with maintenance and operating characteristics is being acquired. Additional units of improved design, lower cost, and various sizes are being purchased, built, and installed. The capital costs for some simple designs appear to be approaching economic viability.[10] Installed costs (1979)

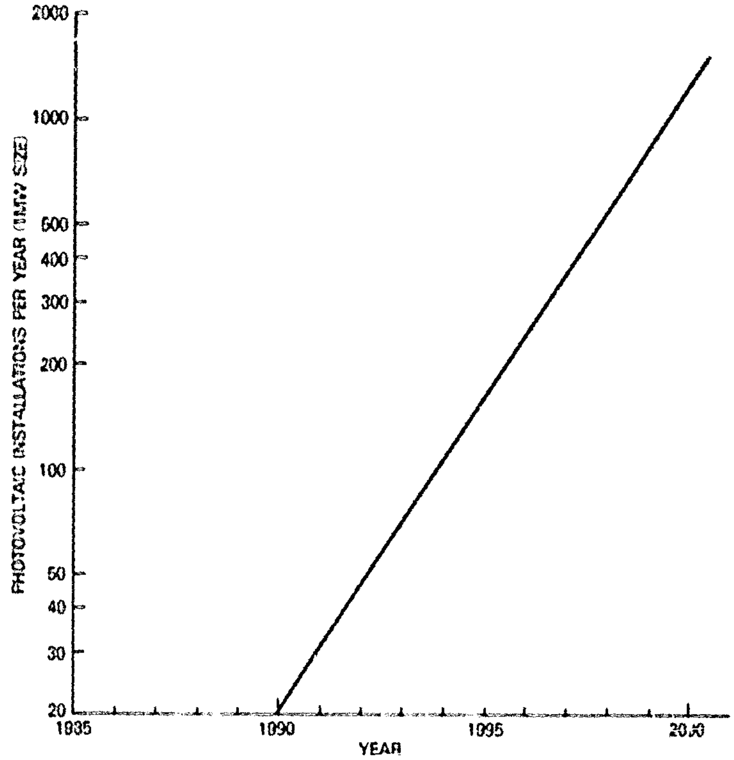


Figure B4.2-1. Growth of Intermediate Size Photovoltaic Installations

in the range of 700 to 800 $/kW for medium size units are reported and large units are in the 1000 to 1500 $/kW range. In the 1980 to 1985 time period, wind generation may be in the commercial stage for localities with high average prevailing wind conditions.

Wind generation does have certain physical constraints. The MW size of wind generation installations tends to have an upper limit, per machine, probably less than 10 MW. Therefore, paralleling of several units will be required to obtain a greater generation capacity at a given site. Sufficient spacing to avoid wind flow interference is required, thus large site size would be needed for multiunit plants. Another constraint will often be insufficient wind to justify wind generation.

A large number of wind power plants were anticipated by the Domestic Policy Review of Solar Energy(11) conducted for President Carter. This memorandum projected scenarios ranging from 0.6 quad conventional energy displacement if "landed price of imported oil is 25 $/bbl," to 1.7 quad as a "maximum practical" value. These displaced energy values translate to approximately 18,000 MW and 50,000 MW of wind power plants assuming an average capacity factor of 0.35 for this type of plant. This figure would equal approximately 1.4 to 3.8% of total national generating capacity in the year 2000.

Another viewpoint is expressed in the EPRI Research and Development Program Plan for 1978-1983,(12) on Page II-55. The following is said about wind generation. "The large wind machines now being developed and tested by NASA appear to be approaching fairly reasonable capital costs (dollars/kW). Since wind is only intermittently available and less predictable than direct solar energy, its integration into a utility grid may present a challenge to generation planners. Because of that, wind machines are likely to be used primarily as fuel displacers and are not likely to comprise a significant percentage of a utility's generation mix. Wind machines are estimated to contribute little to the generation mix (<1%) by the year 2000 and approximately 1% by the year 2020."

An EPRI study(10) provided a preliminary penetration analysis wherein a potential of approximately 6000 MW of wind power plants, using baseline study conditions, were foreseen. Regarding the results, the report states, "The curve using baseline conditions may be considered conservative because it assumes no improvement in cost or efficiency of WTG plants."

If a value of 12,000 MW cumulative by year 2000 (approximately 1% of total capacity) is used for purposes of anticipating monitoring and control requirements, and if the average size plant is 1 MW, this data translates to a large number of plants per year. Assuming that commercial viability for electric utility application begins around 1985, that the equivalent size is 1 MW, and that exponential growth takes place, the number of 1 MW units added per year may appear as shown in Figure B4.3-1. A judgment as to how many 1 MW units per wind power plant installation would have to be made to determine monitoring and control requirements since multiple units would probably be used at electric utility wind power plant sites. (The units may also be larger than 1 MW.) At a typical wind power plant a central control system is foreseen which would direct all the individual units at that plant.

B4.4 FUEL CELL

Fuel cells are a relatively new means of generating electric power for electric utility systems. Application of fuel cells to space vehicles has had good results. However, for space applications the life expectancy is low and the permissible cost is high. It is anticipated that DSG fuel cell plants in the 5 to 25 MW range will use either liquid or gaseous fuel derived from either petroleum or coal. Central station fuel cell plants in the 200 to 700 MW range are being considered for integration with coal gasifiers. Two basic types of fuel cells are receiving major support. They differ in electrolyte material and operating temperature. First-generation fuel cells use phosphoric acid and operate up to 200 °C (low temperature). Second-generation fuel cells include both molten carbonate fuel cells which operate up to 650 °C (high temperature) and advanced phosphoric acid cells. For electric utility applications first-generation, low-temperature phosphoric acid fuel cell technology is in the preproduction-demonstration stage, while advanced technology, high-temperature fuel cells are in the experimental stage.

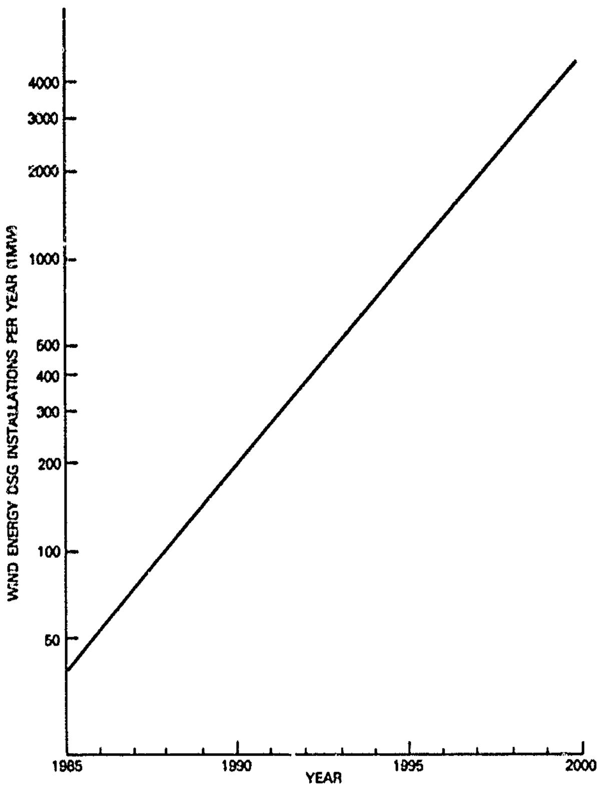


Figure B4.3-1. Growth of Wind Energy Conversion System Installations

Fuel cell power plants offer several major advantages as compared to conventional power plants. These advantages include the following features and characteristics:

- High efficiency over a wide range of part load and plant sizes, including small plants
- Environmental compatibility regarding emissions, minimal water requirements, and low noise level
- Reduced distribution system costs by siting near loads
- System operation flexibility

The DSG fuel cell power plant operating on liquid or gaseous fuel has the ability to accommodate rapid load changes, thus improving frequency regulation and providing rapid response spinning reserve capacity.

A 1 MW phosphoric acid fuel cell pilot unit has operated connected to a utility bus. A 4.5 MW (ac) module is being fabricated and installed on the Consolidated Edison New York system, for testing during the 1980-1981 period. Efforts on commercial prototype definition and commercial feasibility will follow, with limited commercial availability foreseen beginning in 1985[13] if favorable government and industry actions take place.

Regarding future (second-generation) fuel cell technology, cell and cell stack testing have been conducted. Contracts have been awarded and experimental effort has been accelerated on molten carbonate fuel cell technology. These efforts include development of materials and cell configurations and power plant definition for use with coal-derived fuels. Testing is expected to begin in 1981. Contract work includes reference plant designs for 5 MW and 680 MW molten carbonate fuel cell plants. The start of design and construction of a prototype demonstration plant is scheduled for 1984. By 1990 a few prototype molten carbonate fuel cell modules should be operating on utility systems with commercial availability following soon after prototype tests.

Thus, it will take time for the integrity of the designs to be proven, costs to be established, and experience to be gained. These elements are required to establish utility confidence and the related justification for investment in manufacturing facilities to build fuel cells in quantity. Fuel cell power plants are of modular type construction and thus for commercial plants much of the manufacturing and fabrication will be done in factories. Increasing production of fuel cell power plants will therefore directly relate to the number of manufacturing plants and their capacity to produce fuel cell modules. Production capacity will of course depend on utility demand. Capital cost projections, on the basis of large quantity production, are in the range of $350/kW to $450/kW for oil-derived fuel, and $800/kW to $980/kW for coal-derived fuel plants, expressed in 1978 dollars.[14,15]

Low-temperature fuel cell technology is in the preproduction stage and warrants some associated monitoring and control development effort. Monitoring and control capability may be needed in the order of 50 units per year in the period between 1985 and 1990. Beyond 1990, 100 units per year may be anticipated, possibly increasing to larger quantities, depending on fuel cell technology success and acceptable costs.

B4.5 STORAGE BATTERY

Presently, storage batteries are not being used on electric utility distribution systems to assist in supplying peak load energy needs.[16] Existing conventional storage batteries do not appear to be an economically attractive means for storing electrical energy for this function. However, new advanced batteries, such as the sodium-sulfur battery, (Na/S), lithium-metal sulfide (Li/FeS_2), and zinc-chloride (Zn/Cl_2), hold promise of having sufficiently low initial capital costs to make them an economically attractive way of supplying part of the peak load energy needs of electric power systems, and thus producing a "load leveling" effect on the central station generating plants. Projections for higher costs of energy and new central generation capacity requirements provide increasing incentives for economically competitive battery energy storage systems to perform a role similar to that of hydro pumped storage peaking plants. It is fundamental and important to note that energy storage requires adequate central station plant

capacity to provide the energy for charging the energy storage facilities during off-peak periods.

Advanced battery technology is in the experimental stage. DOE, EPRI, manufacturers, and the utility industry are all involved in a major effort to develop advanced battery technology.(17) This includes:

- Cell development and testing, currently in progress
- Testing and demonstration of prototype batteries in the DOE-EPRI-Public Service Electric and Gas Company of New Jersey, Battery Energy Storage Test (BEST) facility. Debugging tests will start in 1980 using conventional lead-acid batteries. After the debugging, an advanced 1 MWh to 5 MWh zinc-chlorine battery will be tested, followed in the succeeding five years by testing of 5 MWh sodium-sulfur and lithium-metal sulfide batteries.
- Testing and demonstration of commercial-sized battery systems in the storage battery electric energy demonstration (SBEED) facility with startup scheduled for 1983 using an improved lead-acid battery.

As an example of the timetable for the development of the sodium-sulfur advanced battery program involving General Electric and EPRI, the following activities are planned:

- Cell Development Phase - through 1981
- Module Development Phase - 1980-1984
- Demonstration Phase - 1982-1985

It has been estimated, in regard to this program, that by 1990, manufacturing facilities can be available with the capability of producing 25 batteries per year, each rated 20 MWh to 100 MWh capacity. According to the previously defined development stages, the timetable for this sodium-sulfur battery program is:

- Until 1983 - experimental
- 1983-1985 - preproduction
- 1985-1995 - commercial

To gain a perspective of battery energy storage capacity potential on a national scale, Reference 16 addresses the needs for energy storage through the year 2000. It is recognized that coal and nuclear fuel will be eventually required to replace most of the existing petroleum and natural gas-fired generating capacity, and the additional generating capacity required by load growth. Reference 16 states, "The net result of deploying 120 GW of new energy storage equipment between 1985 and 2000 is that energy storage will directly substitute for petroleum," and "coal will supply the bulk of the energy for storage."

In Reference 18, it is noted that an anticipated 100 GW of battery storage capacity is included in the year 2000 scenario by EPRI.

Still another look at the transition period from the present to the year 2000 is Reference 19. The battery storage system is compared with gas turbines for the electric load-leveling market. The time period of interest is taken to be 1985 to 2015, by which time it is implied that an earlier introduction of advanced storage batteries is not likely. Further, the influence of battery storage system capital costs which range from $350/kW to $445/kW, are shown to have a very pronounced effect on the market, in MW/year. In Figure B4.5-1 the range of capacity additions/year indicated for year 1990 is 20 to 1000 MW and for the year 2000, 900 to 3000 MW.[19] Also indicated in the report are the influences of escalating fuel costs and the delay introduced by the rate of acceptance of battery storage systems by the utilities. This report serves to highlight the uncertainty of the timing of the actual storage battery market development. However, it does indicate that a large potential market exists for equipment to meet the peak load electrical energy needs and the opportunity for storage batteries to compete for this market.

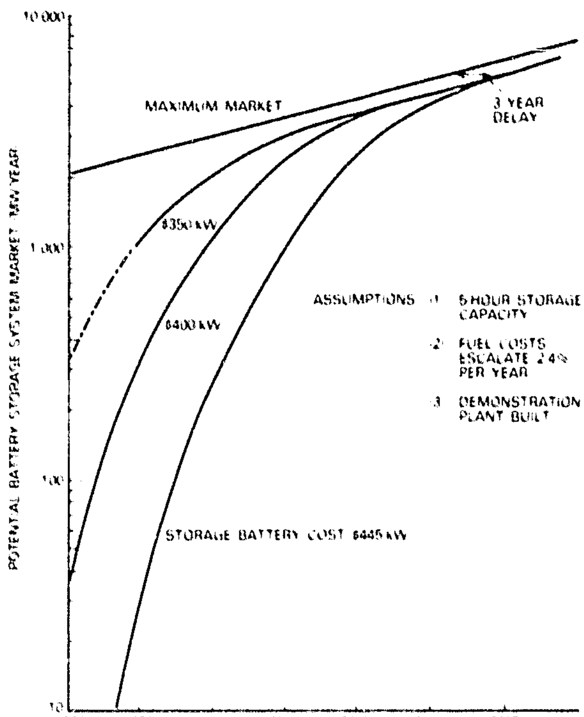


Figure B4.5-1. Effect of Storage Battery Cost on Potential Battery Storage Systems Market

In summary, the advanced storage battery technology should achieve preproduction status in 1985 and should be available for commercial utility operation by 1990. If battery storage capacity additions of Reference 19 are used as an approximation, and 10 MW as an average size installation, monitoring and control facilities would be required at the rate of 2 to 100/year in 1990 and 90 to 300/year in 2000. Reference 18 indicates a battery storage capacity of 100 GW in the year 2000. To achieve this storage capacity would require more installations per year than noted above.

B4.6 HYDROELECTRIC GENERATION

Hydroelectric generation, as applicable to DSG, is represented primarily by small/low head installations. There is renewed national interest in small/low head hydroelectric power because it uses a renewable energy source. A small hydroelectric site is defined by the Public Utilities Regulatory Policies Act (PURPA) as an existing dam with a development potential of 15 MW or less. Low head has been defined by DOE as 20 meters or less of usable head. These hydro units may be classified as a mature technology, and many installations have been made in the past, some before the turn of this century.

For the past 35 years utilities have been retiring small/low head hydro. In that period 577 MW were withdrawn; of this amount 147 MW were retired between 1970 and 1976. The technology base and manufacturing capability still exist although manufacturing capacity has been shrinking from lack of business. With the renewed interest in small hydro units, efforts are mainly concentrated on lower cost designs. The types receiving considerable attention are tube type and bulb type turbine designs, because of their lower cost compared to Francis or Kaplan types. However, some additions to existing power houses will use duplicates of the original units. New small hydro unit installations will most likely include automatic control. Depending on their size, remote control and communications will also be used for better dispatch/control of water use, scheduling, and hydro-thermal coordination. In this respect some new technology will be superimposed on hydro, but hydro is still within the classification of a mature technology.

A DOE Small/Low Head Hydro Program has been established, and in New York State there is an active Low Head Hydro Program supporting a number of installations. There is interest in the government, utility, and private sectors to determine the availability and economic viability of specific hydro sites for expansion and/or development. Economic viability of hydro is principally a result of increasing fuel costs, a factor which is raising the cost of electrical energy production. Over the life of the plant, this produces a favorable hydro benefit/cost ratio when compared to the projected cost of electrical energy generation by fossil-fueled units.

Where hydroelectric plants exist in good condition, and provision for expansion has been included, hydroelectric capacity additions

are the least expensive and easiest to justify economically. Next in economic viability are new additions to existing hydroelectric plants, followed by conversion of existing dams originally built for other purposes to include new hydroelectric facilities. Building new dams and completely new facilities is the most difficult to justify, although this has been done. For example, in some cases it is more economical to build a new plant than to rehabilitate old sites which are in a state of disrepair or deterioration. Thus the capital costs for small low head hydro installations cover a wide range of $/kW. The New York State Energy Research and Development Authority (NYSERDA) has a very active small hydro development program. A NYSERDA study[20] has been made to estimate the cost of small hydro and other renewable energy technologies in New York State. Actual and generic cost estimates were made for sites with reasonable conditions. For generic site estimates involving a good existing dam and requiring new hydro turbine-generator equipment, costs ranged from 349 $/kW to 1936 $/kW. These costs were for 25 meter/3000 cfs and 5 meter/100 cfs hydrologic conditions respectively. For the same hydrologic conditions, a poor dam, and new hydro turbine-generator equipment costs were from 621 $/kW to 3372 $/kW. In an earlier study,[21] sites requiring a new dam had costs ranging from 689 $/kW to 4464 $/kW. As an indication of current projects, the November 1979 issue of DOE's Small Hydro Bulletin listed 15 demonstration projects which had a cost range from 896 $/kW to 1864 $/kW with an average of 1423 $/kW.

In estimating the potential growth for DSG hydroelectric generating capacity a perspective of what the ultimate capacity addition limit is, what is considered practical, and what is presently planned is important. A recent (1977) study by the U.S. Corps of Engineers[22] of potential capacity additions, at all existing dams, is pertinent. This study identified a total potential of 54.6 GW and consisted of the following breakdowns:

Table B4.6-1

POTENTIAL CONVENTIONAL HYDROELECTRIC CAPACITY AT EXISTING DAMS

Type	Potential Capacity (GW)
Rehabilitation of existing hydro dams	5.1
Expansion of existing hydro dams	15.9
Existing nonhydro dams (>5 MW)	7.0
Existing nonhydro dams (<5 MW)	26.6
Total Potential	54.6

Note that this list includes both large and small hydro. Further studies are being made to determine what portion of the potential is available, practical, and economically justified. In addition to the potential listed above, there are potential sites which have no dam. Regarding hydro, the Domestic Policy Review of Solar

Energy[23] presents projections for conventional energy displacement by low head hydro. Several scenarios are given and they range from 0.4 quads (at $25/bbl landed price of imported oil in 1977 dollars) to 0.8 quad as a maximum practical value. Using a 0.014 quad = 1 GW capacity, these displaced energy values convert to 28.6 GW and 57 GW respectively.

In comparison, the DOE Small/Low Head Hydro Program Plan, 1979 (preliminary), lists as the current DOE Program goal 1.5 GW additional capacity by 1985, and 3.0 GW by 1990. No projections are included for year 2000 although an earlier Preliminary Commercialization Strategy Report (1978) projected 20 GW for year 2000. Utility estimates of what might be achieved in small/low head hydro additions range up to approximately 9000 MW by the year 2000.

Assuming all agencies and sources used the PURPA definition of 15 MW maximum site capacity, an average size of 5 MW and a 5000 MW total capacity addition would amount to 1000 units (or plants). This activity would be spread over 20 years with the maximum activity in the middle of this period. On the average this process would amount to 50 units per year. Additional studies are in progress to refine the potential and more definitive data are expected in the near future.

B4.7 COGENERATION

Cogeneration has been employed in the United States since the early 1900's. Thus, it may be considered a mature technology. Since cogeneration is used in many industries, it has many configurations to suit the needs of the various process heat and electric power requirements. Studies are in progress to evaluate the possibilities for expanded use of cogeneration utilizing new energy conversion cycles[25] which are in the early design or experimental stage. Basically the technology, manufacturing capability and capacity, and industry infrastructure already exist for the foreseen conventional cogeneration additions. The percentage of United States electric power produced by cogeneration decreased from 15% in 1950 to less than 5% in 1978 primarily because of relatively low cost electricity available from utilities, low fossil fuel costs, and the reliability of service from electric utilities. With the cost of fuel and electricity increasing rapidly, reconsideration is being given to cogeneration. Until the recent price increases, many potential cogeneration systems could not achieve the 20% after-tax return on investment that most of industry considers a minimum for discretionary capital investment. Although this picture is improving, there are other impediments which hinder implementation of cogeneration additions. These involve legislation, regulation, regulation entities, corporate policy, and power rate structures. Thus, encouraging accelerated implementation of cogeneration is a very complex industry-utility-governmental process.

Assessments of market readiness and potential penetration have been made by DOE. The task force[24] which was assigned

predicted that "potential will increase through the year 2000 generally in moderate sizes (10 MW) and at high utilization rates (above 70% annual capacity factor)." The task force also provided a forecast of expected new generating capacities from cogeneration systems, depending on degree of governmental action and encouragement as follows:

Table B4.7-1

EFFECT OF GOVERNMENTAL ACTION ON COGENERATION CAPACITY

Governmental Action	Cumulative New Cogeneration Capacity in Year 2000 (GW)
No added governmental action	25.9 - 79.4
With NEA actions	13.4 - 41.0
With other governmental action	17.8 - 69.6
Total	57.1 -190.0

Even a conservative estimate of 30 GW would amount to 3000 new cogeneration units of 10 MW each between 1980 and 2000 for an average of 150 per year.

To provide an indication of the differential cost of electric power generation capability included with a process industry plant (cogeneration) as compared to a process industry plant without electric power generation (no cogeneration), information was obtained from the CTAS study[25] recently completed by the General Electric Company for NASA/DOE.

As a reference, a 10 MW electric power demand and 137×10^6 Btu per hour at 300 °F cogeneration plant size was chosen. For these power and heat conditions, cost estimates were made of state of the art type power generation equipment in cogeneration configurations. Next, process heat producing plants of the same generic type were configured and capital costs were estimated. Finally, the difference between cogeneration and no cogeneration capital costs were divided by the rated cogeneration kW output to determine incremental dollars per kilowatt. This calculation is represented by the following equation:

$$\$/\text{kW} = \left[\frac{\text{capital cost of cogeneration} - \text{capital cost of no cogeneration}}{\text{kW generated on site}}\right]$$

The cases chosen to provide an indication of the relative incremental capital cost differences for several types of prime movers and two types of fuel are given in Table B4.7-2.

While these incremental capital costs give an indication of cogeneration versus no cogeneration costs, economic analyses are usually based on overall comparisons.

These economic analyses include basic factors of:

- Minimum Capital Cost
- Rate of Return on Investment
- Minimum Cost of Energy

Such economic analyses are beyond the scope of this report. Reference 25 provides additional information.

Table B4.7-2

EFFECT OF FUEL TYPE
ON INCREMENTAL CAPITAL COST OF COGENERATION PLANTS

Fuel Type	Prime Mover Type	Incremental Capital Cost,* \$/kW (in 1978 \$)
Residual Oil	Steam Turbine	360
Residual Oil	Gas Turbine	580
Residual Oil	Diesel Engine	915
Coal with Flue Gas Desulfurization	Steam Turbine	400

*Incremental capital cost of cogeneration versus no cogeneration for 10 MW electrical power demand and 137×10^6 Btu per hour steam at 300 °F.

B4.8 ANTICIPATED TRENDS IN DSG USE

The preceding estimates of DSG potential growth in this section have been prepared by investigating these estimates on the basis of individual DSG technologies. An effort is made here to synthesize and to balance the interrelationships of competing technologies and estimates: the total installed capacity of each type DSG by the year 2000; the total number of additions of utility-sized DSG units by technology; and the anticipated number of installations per year by technology for the years 1990 and 2000. A note is also made referring to the number of small-sized DSGs estimated to be present by the year 2000.

This information is summarized in Table B4.8-1 and should be considered as a possible scenario of what could happen rather than as a statement of what will happen. The anticipated date of commercialization for each DSG technology seems to be reasonably well agreed upon by many authorities. The total capacity additions also seem reasonably well agreed upon. The anticipated "average size," which influences the number of installations per year, is probably less generally agreed upon. This "average size" is indicated by the spread in the estimated numbers of units to be installed per year.

Table B4.8-1

DSG TECHNOLOGY CURRENT STATUS AND ANTICIPATED USAGE IN YEAR 2000

DSG Technology	Present Status	Anticipated Date of Commercialization	Total Additions Output (GW)	Total Additions Number of Units	Anticipated Installations per year 1990	Anticipated Installations per year 2000
Solar Thermal	Experimental	1990	2	2000 @ 1 MW	10-20	100-400
Photovoltaic	Experimental	1990	2	2000 @ 1 MW	20-50	200-500
Wind	Preproduction	<1990	6	3000 @ 2 MW	50	600
Fuel Cell	Preproduction	<1990	3	600 @ 5 MW	>50	>100
Battery	Experimental	1990	15	3000 @ 5 MW	2-100	200-600
Hydro	Mature	Now	6	1200 @ 5 MW	60	60
Cogeneration	Commercial	Now	30	1500 @ 20 MW	60	150
			64*	13,300 Total Estimate		

*Assumes: (1) 5% of U.S. total generation is dispersed storage and generation, units of average size indicated.

(2) This does not include small DSGs (assumed to be 20 kW average), and if these are 0.5% of the United States total, this amounts to 6 GW and 300,000 units.

It should be noted that the total installed capacity of small DSGs is estimated to amount to only 10% of the total capacity of DSGs installed by 2000; their average size at 20 kW assumes that there are many wind and solar photovoltaic units of residential size (10 kW or smaller), included in the averaging process, along with larger units for multiple housing units, public buildings, and commercial load centers. A discussion of some of the estimates involved in these data is contained in Section 5.9.

Section B5

IMPLICATIONS OF DSG GROWTH ON MONITORING AND CONTROL DEVELOPMENT

From the preceding section it appears that there will be an increasing need for equipment to handle monitoring and control of dispersed storage and generation on distribution networks. Although the amount of generation by DSG sources may be small compared to the existing capacity for electric generation, perhaps 4 to 10% by the year 2000, the number of communication equipments for accomplishing monitoring and control may be large. Thus one must consider monitoring and control requirements for DSG in parallel with development of the DSG technologies.

Although the selected DSG technologies have different detail characteristics, it is desirable that a general method of monitoring and control be developed which will be applicable to any of them.

The selected DSGs described in Section B4 may be divided into groupings according to the expected time of their availability and potential growth. For example, some, such as fuel cells and storage batteries, hold promise of the greatest long-term potential growth. However, for the present, these new technologies are not generally available for extended experimental use for monitoring and control development. To a limited degree, the Public Service Electric and Gas Battery Energy Storage Test (BEST), and the Consolidated Edison fuel cell facilities may be available for monitoring and control development. If work on monitoring and control of experimental DSGs interferes with the development testing of the DSG itself, it is not likely that work on monitoring and control would be closely coupled to the development testing stage.

DSG technologies, such as hydro, are mature and limited in potential growth. However, when the retrofitting of existing units and new or expanded capacity additions are considered, the need for monitoring and control equipment will probably be sufficient to warrant development. A further user incentive for monitoring and control for DSG hydro units is that this capability will enhance usefulness (value) and thus strengthen the market for hydro generation.

Other DSGs, such as wind and cogeneration, represent attractive growth potential and are sufficiently well-established to warrant working out monitoring and control details. Their performance and use may become more attractive and effective through the introduction of improved monitoring and control.

When DSG monitoring and control requirements are defined, it will be important to provide flexibility in the functional design requirements. While the mature DSG technologies provide a basis for requirements definition, new DSG technologies may have new

or additional requirements. Thus, provision for functional variations and additions should be anticipated when defining monitoring and control system design requirements.

Section B6

SUMMARY

Although the future growth rate of electrical energy generation in the United States is expected to be lower than its historical growth rate, it will remain positive for the remainder of the 20th century. The electrical energy growth rate is expected to remain higher than that of total energy growth because of the effect of an increasing proportion of electrical-to-total energy at the consumer level. Total energy forecasts for the year 2000 cover a range of 95 to 140 quads. An installed generating capacity of 1200 to 1300 GW is forecasted by recent DOE and EPRI midrange projections.

Regarding DSG, capacity forecasts for the year 2000 cover wide ranges and are represented by various organizations. For optimistic assumptions regarding cost and governmental policy/regulation, and so forth, an installed DSG generating capacity in the range of 4 to 10% of total national generating capacity might be achieved. This capacity could represent a total of 50 to 130 GW. The majority of this amount would consist of contributions from mature technologies such as cogeneration and hydro. Amounts of less than 1% each might be expected from solar thermal, photovoltaic, fuel cell, and wind technologies, but under favorable conditions use of these new technologies could be accelerating rapidly by the year 2000. Thus 50 to 130 GW, assuming an average size of 5 to 10 MW, would represent 5,000 to 26,000 DSG generating units, a significant number.

While the assumption that the average DSG size might be in the 5 to 10 MW range is based on estimates of the types of DSGs which would comprise the major share of the installed DSG capacity, there also are possibilities of a large number of small residential or small commercial business installations. These will be primarily wind and photovoltaic DSG systems with a possibility of some fuel cells being utilized.

For the year 2000, if 25% of the 12,000 MW wind DSG capacity postulated in this report were 10 kW sized units, 300,000 units are implied. Similarly, if 25% of the 5000 MW of DSG sized photovoltaic capacity is in 10 kW sized units, 125,000 units are implied.

Storage battery technology also has potential for substantial capacity by the year 2000 if cost goals are met. The EPRI Research and Development plan for 1979-1983 indicates a possibility for 100 GW by the year 2000. If these are assumed to average 10 MW, then 10,000 units are represented.

Thus, with regard to monitoring and control of DSGs, the potential market represents a large number of units to be served. Therefore, it appears advisable to investigate and define the requirements for monitoring and control of DSGs.

It is recognized that the DSG market potentials indicated are based on optimistic assumptions regarding costs and favorable government policy and associated regulation and incentives. Since these factors inject uncertainty into all forecasts, economic and political factors should be followed closely by utilities, suppliers and interested agencies in order for them to be appraised of changing conditions affecting DSG technologies and associated monitoring and control requirements.

Section B7

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